Study Performed for the

EVALUATION OF WASTEWATER TREATMENT CAPABILITIES OF CALICHE-TYPE SOILS

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EVALUATION OF WASTEWATER TREATMENT CAPABILITIES OF CALICHE-TYPE SOILS

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ABSTRACT

Caliche soils, or weathered limestone soils of high calcium carbonate content and low organic content, are common in regions with limestone sedimentary geology and arid to semi-arid climate. Such conditions are common to the Central Texas Hill Country and Highland Lakes areas around Austin, Texas. Caliche soils are very different mineralogically, texturally, and structurally than other types of soil. Currently in the State of Texas there are no state-wide standards, other than those for soil hydraulic properties, for the design and construction of on-site wastewater treatment systems in caliche soils.

Experimental studies and monitoring were performed to investigate the wastewater treatment capabilities of several different caliche soils using a range of loading rates. The experimental results from column studies indicated that oxygen demanding materials decayed over short distances in these soils. The high calcium carbonate content of the caliche soils lead to solutions well buffered with respect to pH and alkalinity. Nitrification rates are very rapid in these soils, which are buffered at the optimum pH ranges for nitrosomonas growth.

The low organic carbon content of caliche soils would be expected to contribute to lower denitrification rates, as compared to other soils with higher levels of organic carbon. Nitrate concentrations in treatment systems effluent may be the limiting pollutant in the determination of appropriate loading rates, or land area requirements for land-based treatment, or for pretreatment requirements prior to final land disposal in caliche-type soils. Pathogen reduction may also be a consideration for the design of appropriate on-site wastewater treatment systems in these conditions.

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INTRODUCTION

Caliche soils, or weathered limestone soils of high calcium carbonate content and low organic content, are common in regions with limestone sedimentary geology and arid to semi-arid climate. These soils cover large areas of Texas, particularly in Central Texas where there are limestone formation outcrops, and where lower population densities or conditions unfavorable to the construction of centralized sewer systems favor the use of on-site wastewater treatment systems. These materials tend to have highly variable hydraulic conductivities, and are often intermixed with clays or other soils. Caliche soils overlying karstic formations, such as areas within the Edwards Aquifer recharge zone in Central Texas, may result in the rapid transport of pollutants to the groundwater aquifer during rainstorm flushes.

Previous studies and reports have suggested that conventional on-site systems designs might not provide adequate treatment in these soils. Limestone in soil has been proposed as useful in controlling the solubility of phosphate, but nitrification results rapidly in aerobic unsaturated limestone soils (Brandes et al., 1975; Chowdhry, 1977; Khanbilvardi and Long, 1985; Simon, 1986; Simon et al, 1986; Whelan, 1988; Williams and Cooper, 1986). In their zones of higher hydraulic conductivity caliche soils typically have unsaturated aerobic conditions near the surface of the soil profile.

For denitrification to occur, conditions must include an organic rich anoxic media. However, most caliche soils are relatively low in organic carbon content. Thus, with a high potential for nitrification, in areas with relatively high infiltration rates there is the opportunity for the rapid transport of nitrate either to groundwater, or to surface water supplies through fractures and lateral bedding planes in limestone formations. Federal standards for groundwater protection limit nitrate levels to less than approximately 45 mg/L (as nitrate, or 10 mg/L as nitrogen). Karstic or fractured formations and lateral bedding planes of weathered limestone may also provide the opportunity for the transport of bacterial and viral pollutants to ground or surface water supplies.

Currently there are no state standards in Texas, other than those for hydraulic properties of the soil, for the design and construction of on-site wastewater treatment systems in caliche type soils. Without conducting a study to evaluate the wastewater treatment capabilities of these soils, it is not known whether conventional designs based primarily on hydraulic soil properties provide adequate treatment. This study was performed for this purpose.

PROJECT DESCRIPTION AND RESULTS

The study consisted of two principal types of investigation: (1) laboratory soil column studies, and (2) field monitoring of two existing onsite wastewater treatment systems.

Laboratory soil column studies were performed for several types of caliche soil, along with sandy loam soil columns for comparative purposes. The purpose of this portion of the study was to evaluate the treatment capabilities of caliche-type soils under very controlled and conservative conditions. That is, with the wastewater flowing through columns packed with caliche soils in such a way as to minimize the potential for any short circuiting which might occur for in-situ conditions. In this way, on one hand pollutant attenuation might be superior to what could be observed in the field, since the potential for channeling of effluent would be reduced. On the other hand, some of the potential removal mechanisms for constituents such as nitrogen would be reduced or eliminated. A discussion of this is presented in the following section.

Based upon some of the results obtained from the column investigations, a bench scale system was developed and set up for testing the effectiveness of applying a carbon source to wastewater which had been pretreated using a sand filter, and applying this to the soil columns. The last phase of the study consisted of the field monitoring of two existing on-site systems.

The laboratory column and field monitoring phases of the project are discussed separately below, followed by a discussion of the results for each phase, and conclusions and recommendations from the study.

Laboratory Column Studies Set-up

Caliche soils were collected from several locations to the west of Austin. Several different parent limestone formations were selected using maps of local geology, Soil Conservation Service surveys and previous geologic studies. Approximately ten to twelve cubic feet of soil were removed (using picks and shovels) and collected from the upper horizons of each of three different hill country sites. These were transported to the University of Texas Civil Engineering building, where columns were constructed and packed with these three types of caliche soil. In some cases, caliche/limestone material in the upper horizon varied considerably (in a horizontal direction) at the same site, and samples from each type were obtained and analyzed separately. Approximately 10 cubic feet of sandy loam were obtained from a local supplier, and also transported to the University for use in other columns.

A total of six visibly different soils were obtained. These included a yellow/milky and a gray weathered limestone soil from an area determined from maps of local geology to be in the Glen Rose formation. Two different caliche-type soils were obtained from an area overlying the Edwards formation. One of these was very reddish in color, and the other more of a yellow color. A caliche-type soil with much finer particle sizes and significant clay content was obtained from an area which, according to local geology maps, is in the Walnut formation. Mineralogical analyses were conducted for all of the soils obtained, including the sandy loam, and used for the column studies. The results of those analyses are included in Attachment 1.

Columns were constructed of two different sizes of PVC (Schedule 80) pipe, with the larger size used for the caliche-type soil, and the smaller for the sandy loam. The caliche soils used for the study had maximum particle sizes of about one to one and a half inches. A diameter of column to diameter of maximum particle size ratio of approximately 10 was considered adequate to minimize wall effects of the columns when wastewater was applied. Particles greater than one and a half inches were removed from the soil used to pack the columns. Twelve inch diameter (inside diameter) PVC pipe was used for the caliche soil columns. Eight inch PVC pipe was used for the sandy loam columns, since the maximum particle size for this soil was much smaller.

Attachment 2 shows the materials used for the construction of the columns, and a detailed description of the method by which the columns were constructed. After the columns were constructed, they were carefully transported to the Center for Environmental Research (CER) laboratory located at the City of Austin's Hornsby Bend sludge treatment facility, where the testing was performed. Photographs of the laboratory set-up at CER are presented in Attachment 3.

After the columns were set up at the CER laboratory, in order for wastewater to gravity-drain freely through them, it was necessary to "back flush" the columns with water to remove air pockets. Columns packed with the Walnut formation soils could not be back flushed, even after a period of months, due to the very low permeability of that material. Therefore, those columns were never used for wastewater application. After backflushing the other columns, the saturated hydraulic conductivity of each was measured. The columns were then allowed to drain.

After draining the columns, de-ionized water was applied by gravity flow from cubitainers to the columns, and samples were taken from the caliche soil columns to obtain background levels for constituents of concern. Cubitainers were placed on stands above the top of the columns with tubing used to deliver the deionized water (and later the wastewater) to the columns beneath the surface of the soil in the column (see photos in Attachment 3).

Arrangements were made to obtain septic wastewater from a local company which pumps residential septic tanks. A source of septic wastewater was not available at the Hornsby Bend facility. A 165 gallon polyethylene tank with a 2" drain valve at the base was buried into the side of a hill, and used to store wastewater (see photo, Attachment 3). Wastewater was then pumped, using a hand pump, into a 5-gallon day tank and taken to the laboratory for application to the columns as needed. The day tank was covered with a black plastic bag to block out light, and the lights in the laboratory were turned off when the lab was not in use in order to minimize algae growth in the cubitainers and tubing used for wastewater application. Attachment 4 shows a diagram of the laboratory column set-up.

A period of a few days typically elapsed between times when fresh wastewater was brought to the Hornsby Bend site. Therefore, at least some change occurred in the wastewater strength during this period. However, the influent quality of wastewater applied to the columns was sampled and analyzed whenever samples were collected and analyzed for the effluent from the columns.

To the extent practicable, more than one soil column was set up for each soil type used in order to compare the effects of higher and lower loading rates. The range of loading rates of wastewater to the columns was based upon the current Texas design criteria for onsite systems. For Texas, these rates appear to be based upon the hydraulic characteristics of the soil, and upon experience with the performance of systems using these application rates. Since hydraulic limitations of the soils must always be considered for land treatment systems, and the pollutant attenuation capabilities of these (and many other) soil types has not yet been quantified, the accepted loading rates based upon hydraulic considerations was used as a starting point for this study. Table 1 summarizes the soil type used for each column to which wastewater was applied, along with the measured saturated hydraulic conductivity and the wastewater loading rate for that column.

Wastewater was applied to the columns for a period of several weeks before any samples were taken in order to allow the columns to reach relative equilibrium, and for residual water to exit. Wastewater was usually applied at least five times weekly. Samples were taken and analyzed on a weekly basis during this phase of the study.

Parameters analyzed from samples included nitrate, nitrite, ammonia, inorganic and total carbon, and total phosphate.

Table 1
Summary of Soil Column Set-up

Column #1:

Soil Type:	Sandy loam
Column Size:	8"
Measured Sat. Hydraulic Conductivity:	2.2 x 10-5 cm/s
Wastewater Loading Rate:	0.09 gpd

Column #2:

Soil Type:	Glen Rose Gray
Column Size:	12"
Measured Sat. Hydraulic Conductivity:	3.1 x 10-5
Wastewater Loading Rate:	0.343 gpd

Column #3:

Soil Type:	Edwards "Milky"
Column Size:	12"
Measured Sat. Hydraulic Conductivity:	1.84 x 10-5
Wastewater Loading Rate:	0.45 gpd

Column #4:

Soil Type:	Edwards "Milky"
Column Size:	12"
Measured Sat. Hydraulic Conductivity:	2.28 x 10-5
Wastewater Loading Rate:	0.2 gpd

Column #5:

Soil Type:	Glen Rose Yellow
Column Size:	12"
Measured Sat. Hydraulic Conductivity:	3.4 x 10-5
Wastewater Loading Rate:	0.2 gpd

Column #6:

Soil Type:	Sandy Loam
Column Size:	8"
Measured Sat. Hydraulic Conductivity:	1.99 x 10-5
Wastewater Loading Rate:	0.2 gpd

Table 1 (Continued)

Column #7:

Soil Type:	Edwards Red
Column Size:	12"
Measured Sat. Hydraulic Conductivity:	8.41 x 10-5
Wastewater Loading Rate:	0.343 gpd

Column #9:

Soil Type:	Glen Rose Yellow
Column Size:	12"
Measured Sat. Hydraulic Conductivity:	7.81 x 10-6
Wastewater Loading Rate:	0.45 gpd

Column numbers 8 and 10 did not backflush in time to begin testing until long after wastewater application began for the other columns. Those columns were not used.

Column number 9 clogged shortly after wastewater application began.

Column numbers 11 and 12 were packed with a caliche soil from the Walnut formation. These columns did not backflush for a period of about one year, and were never used.

Bacterial measurements were not made during the column study phase of the project, due primarily to the fact that column soils were packed so as to prevent channeling of effluent, and would thus filter most bacteria from the influent wastewater. Overall project costs were a consideration, and it was thought to be more cost-effective to analyze for indicator bacteria during the field monitoring phase of the project.

<u>Summary and Discussion of Results of Laboratory Column Studies</u>

Background levels of nitrate (as nitrogen) measured for the caliche soil columns were very low. These varied from non-detectable to 1.7 mg/L (this higher level was measured for Column #7). Background levels of total carbon for the sandy loam soils were significantly greater than for most of the caliche soil types, as expected.

Several columns showed a tendency to become saturated and clog following the first few weeks of wastewater application. This was not particularly surprising, inasmuch as there would have been an opportunity for a biomat to form in the columns where the wastewater was applied during that period. Only one of the two sandy loam soil columns continued to accept wastewater throughout most of the laboratory study period (Column #1). Wastewater was applied, and samples collected as possible to the columns which continued to drain, over a period of several months. Results below are reported for those columns which did not clog and prevent regular wastewater application, and from which samples could be collected.

All of the columns demonstrated excellent nitrification performance. With total Kjeldahl nitrogen (TKN) and/or ammonia/ammonium levels of applied wastewater often in excess of 100 mg/L, effluent from the columns had ammonia levels below 1.0 mg/L in all cases.

Overall, there was a trend of decreasing levels of nitrate over time for the effluent from the sandy loam soil column. Measured nitrate (as nitrogen) levels for the sandy loam Column #1 started at approximately 40 mg/L, and decreased to non-detectable levels during the latter weeks of study. For sandy loam Column #6, which showed signs of clogging with its higher application rate (0.2 gallons/day as compared to 0.09 gallons/day for Column #1), nitrate-nitrogen levels returned to higher levels after the column began to clog (after it had apparently exceeded its hydraulic loading capacity).

Generally the opposite trend was observed for nitrate measurements from the caliche soil columns. Nitrate-nitrogen levels for Column #4 varied from as low as 2.8 mg/L to 29.0 mg/L several weeks later. Measurements for Column #2 varied from as low as 10.7 mg/L to 21.6 mg/L (with the higher measurement taken approximately one month later). All measurements for Column #7 after wastewater application began were relatively high (without using any pretreatment), varying from 26.8 mg/L up to 35.7 mg/L.

Results for Column #'s 1, 2, 4, and 7 are presented in Table 2. Average influent ammonia concentrations are shown for the period during which the effluent measurements were taken (TKN concentrations were not available for most of those days). As mentioned previously, all measured effluent concentrations of ammonia from all of the columns were less than 1.0 mg/L.

Only one of the caliche soil columns (Column #7) showed significantly lower average nitrogen removal as compared with the sandy loam column (Column #1). Both caliche soil Column #'s 2 and 4 showed similar average nitrogen removal as compared with the sandy loam soil. As noted above, however, different trends of removal were observed during the earlier and latter periods of observation for the caliche and sandy loam soils. It should also be noted that the sandy loam Column #1 was loaded at a relatively low application rate on an areal basis.

Total phosphate measurements for effluent from all of the columns were consistently very low. Only two measurements for all of the columns out of a total of 23 measurements, were greater than 1.0 mg/L (one measurement of 1.3 mg/L, and another of 2.5 mg/L). Total organic carbon levels for effluent from all columns was on all occasions very low. Nitrite measurements were in all cases less than 1.0 mg/L for column effluent.

Levels of effluent nitrate-nitrogen measured for all of the soil columns could overestimate what might occur for onsite systems operating in those environmental conditions. Factors potentially contributing to that include:

(1) Application of septic wastewater to the columns occurred only once daily, with the entire design loading applied at that time;

(2) There was no potential for vegetative uptake of nitrogen in the columns;

(3) Some of the potential sources of organic carbon in the soil (such as decaying vegetative matter) would not be available in the laboratory columns, and that combined with the fact that a full day's loading of wastewater was applied in a very short time period would provide less opportunity for denitrification processes to occur.

Table 2
Average Influent and Effluent Nitrogen Data for Selected Soil Columns

Column No.	Average Influent NH3-N Conc. (mg/L)	Average Effluent NO3-N Conc. (mg/L)
1	94.6	16.0
2	120.9	12.5
4	76.2	9.7
7	71.9	31.0

NOTE: Influent TKN concentrations were not available for most days. Total influent nitrogen levels would be higher, including organic nitrogen.

Effluent ammonia concentration measurements were less than 1.0 mg/L for all soil columns, on all occasions.

The laboratory column studies showed that under those particular conditions, similar levels of average nitrate-nitrogen removal tended to occur for caliche soils as compared with the sandy loam soils used for the study. However, the caliche soil columns showed decreasing removal over time as compared with the sandy loam column, which showed increasing nitrate-nitrogen removal. Given this trend, had there been an opportunity to observe the performance of the columns over a longer period of time (ie. had further observations not been prevented by clogging of most of the soil columns), the average nitrogen removal by the sandy loam soils might have been significantly better overall than for the caliche soil columns.

Nitrification appeared to occur very readily for all of the columns. Total phosphate removal was excellent, as would be expected, for all of the soils used in the columns.

The principal objective of this study was to evaluate the onsite wastewater treatment capabilities of caliche-type soils for conventional design, and identify potential environmental impacts of systems in those conditions. Another element of the study was to identify possible improvements to existing designs which would likely be cost-effective and provide for adequate onsite treatment without adverse public health or environmental impacts. Based upon the results of this portion of the study it was determined that methods for enhancing nitrogen removal might be appropriate for designs of systems in these conditions, as compared with designs in more organically rich and deeper soils.

<u>Bench Scale Laboratory Set-up for Enhanced Nitrogen Removal</u>

Large-scale wastewater treatment operations frequently use an additional carbon source such as methanol to improve denitrification processes, and enhance total nitrogen removal. Previous studies for small onsite systems have indicated that the use of greywater can be effective as a source of organic carbon to enhance the denitrification process (Biswas,1981, 1983, 1985; Laak, Parese, Costello, 1981). One study found that there was about a 1:1 ratio between greywater and methanol, in terms of their effectiveness as carbon sources for denitrification processes for certain onsite system designs (Laak, 1981). Nitrogen concentrations in greywater tend to be lower than for blackwater. So for some designs it may be more desirable to utilize greywater rather than blackwater as a source of carbon to achieve enhanced total nitrogen removal.

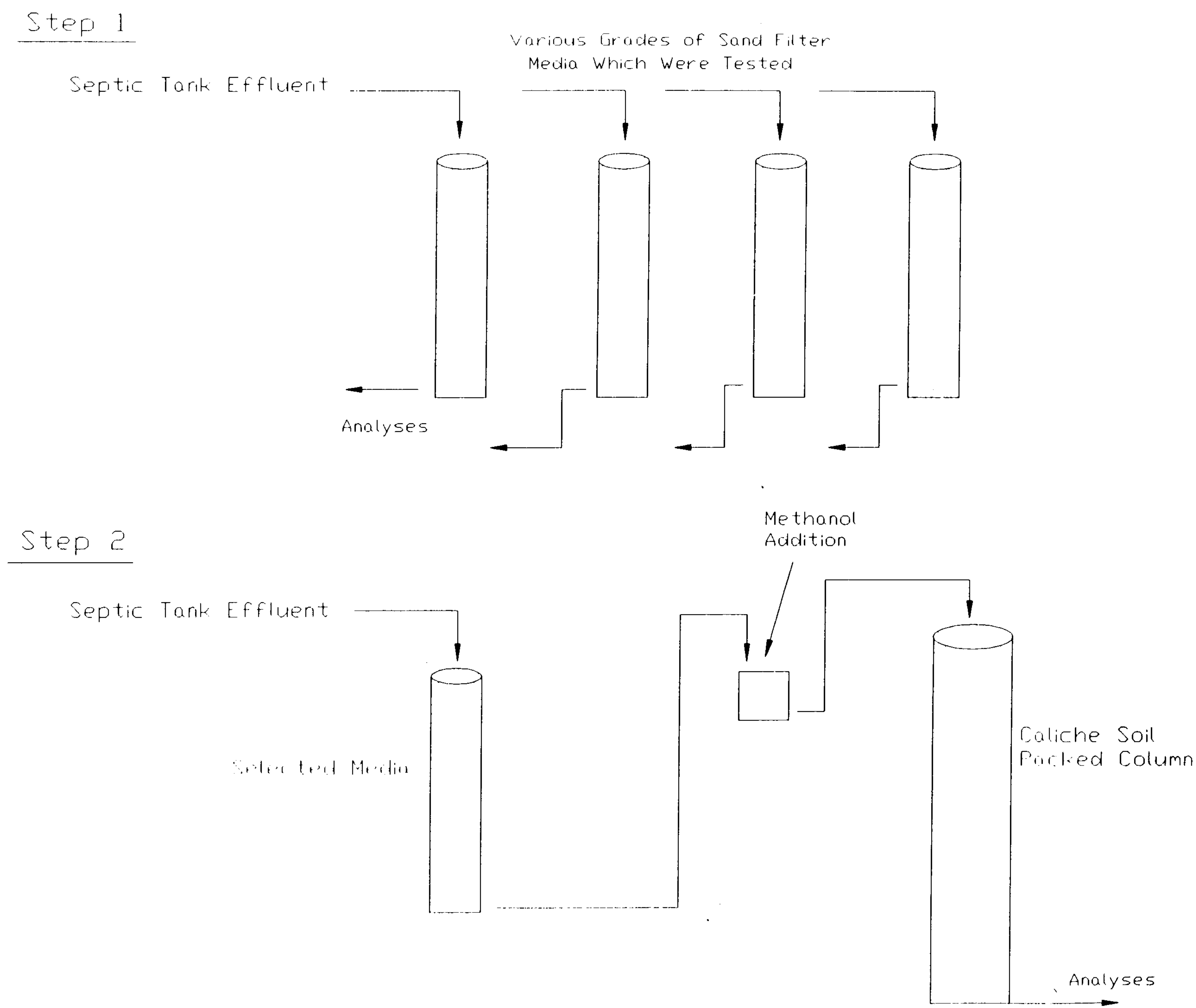
This approach is one of several which might allow for a relatively cost-effective method of achieving adequate nitrogen removal for caliche-type soils. A very short-term bench scale set-up was developed and tested in the CER laboratory to evaluate the effectiveness of adding a separate source of organic carbon to nitrified wastewater for enhancing total nitrogen removal. Researchers commonly use methanol rather than greywater, due to the availability of reliable sources of methanol and the ability to control chemical quality. Since no reliable source of greywater was available at or near the CER laboratory, methanol was used as the carbon source. Septic tank effluent which had been filtered through a course sand media was dosed with methanol prior to applying the mixture to the caliche soil column. A schematic of that set-up is shown on Figure 1, and in photographs in Attachment 3.

For the filtration media, three different grades of sand, and a combination of two of these sands, were tested for their effectiveness in nitrifying septic wastewater (see Figure 1 and photographs in Attachment 3). Four inch diameter columns (plexiglass) were used which were approximately thirty inches in length. The effective filtration depth of the columns was just over two feet. It was desirable to use a relatively coarse grade of sand in order to minimize clogging at the surface. However, at the depth of filter used, it was necessary to use the finest of the three grades of sand tested (fill sand) in order to achieve adequate nitrification. This grade of sand yielded approximately 85% ammonia removal.

Some previous studies (Laak; Warnock and Biswas) have indicated that optimal carbon to nitrogen ratios (C:N) for denitrification in onsite systems is approximately 4:1 to 6:1. Relatively conservative assumptions were made in determining the amount of methanol to apply to the nitrified wastewater. Accepted average nitrogen concentrations for greywater and blackwater were used (with greywater including all non-toilet wastewater flows). The same total organic carbon concentration was assumed for both greywater and blackwater. It was further assumed that all of organic carbon was removed from the septic wastewater through the filtration process.

Column #7, which contained a reddish caliche soil obtained from an area overlying the Edwards formation, was used for testing this process. The volume of methanol to be combined with the nitrified wastewater (0.3 ml/day) was based upon the above C:N ratios and assumptions, and the amount of wastewater applied daily to this column (0.343 gallons/day). This process was tested for several weeks, until the sand filter column used for nitrification began to clog in the top few inches of sand (see photos, Attachment 3). The same wastewater loading rate was used for Column #7 as shown in Table 1. The total time required to filter the raw septic wastewater, add the methanol, and begin applying the mixture to the column varied from about 30 minutes to an hour, depending upon the time required for filtration (this time

Figure 1
Small Scale/Short-Term Column Studies Set-up



increased over a period of weeks due to the development of a clogging layer in the sand).

Summary and Discussion of Results from Bench Scale Enhanced Nitrogen Removal Set-up

After approximately six weeks of applying the mixture of nitrified wastewater and methanol to Column #7, effluent nitrate-nitrogen levels for samples collected from that caliche-soil column were below detectable limits on the ion chromatograph. The average influent ammonia concentration measured during this period was 82.1 mg/L.

These results were not unexpected, considering basic nitrogen removal processes for domestic wastewater treatment systems. The increased nitrogen removal was most likely due to denitrification because, (1) very little volatilization of ammonia would have occurred due to the fact that the wastewater was always applied below the surface of the soil in the columns, and (2) soil columns did not have any vegetation for uptake by that mechanism.

This type of process is just one of several which might be used for systems designs for enhancing nitrogen removal, should that be determined to be necessary for these soil/geologic conditions. However, as with most sand filtration processes, due to the tendency for filters to develop clogging layers near the surface, some means of either backflushing or removing the upper layers of material would need to be provided. Routine inspection of systems using filtration would also be recommended. The use of greywater as a carbon source for denitrification processes might only be cost-effective for new homes, in which the plumbing could be separated initially.

Field Monitoring Well Installation at Two Existing On-site Systems

Although laboratory column studies can provide valuable information, particularly through side-by-side comparisons of the performance of various soils, it is critical to obtain monitoring data from operating residential onsite systems in order to adequately evaluate their performance in particular environmental conditions.

For this phase of the study, permission was obtained to install monitoring wells at two residences with onsite wastewater systems in western Travis County. Only onsite systems which had been designed and installed in accordance with current Austin-Travis County standards were selected for monitoring. To effectively evaluate the performance of current designs in these soils, it seemed appropriate to select systems which were functioning in accordance with current design standards and guidelines.

One of the two systems selected is located in karstic limestone conditions, with weathered bedded limestone near the surface. This system is of conventional design, with the effluent distribution system laid in trenches such that there is gravity flow from the septic tanks (two in series) to the distribution lines. The system was upgraded several years prior to the time when monitoring wells were installed, wherein a second septic tank was installed to increase the capacity of the system. This residential system was designated Site No. 1.

The second site (Site 2) is located in an area overlying the Glen Rose formation, according to maps of local geology. Road cuts in this area show layers of weathered bedded limestone intermixed with layers of limestone rock. This system was a conventional low-pressure dosing system, with two effluent distribution trench systems. Arrangements were made with the property owner to apply effluent only to the area where the monitoring wells were installed during the period when samples were collected.

Two monitoring wells/lysimeters were installed at each of the two sites, since preferential flow patterns may readily occur in these geologic conditions, and two wells would increase the likelihood of capturing effluent from the systems. All four wells were relatively shallow, due to the fact that bedrock was reached fairly quickly during drilling. At each site the two monitoring holes were drilled fifteen to twenty feet apart, and approximately five to ten feet downhill from the nearest effluent distribution trench line. Screened (coarse PVC screen) piping was installed in each monitoring well, and sealed at the surface to prevent surface water intrusion.

The installation of monitoring wells at residential sites in these conditions was found to be very difficult. Homes were carefully selected, not only in terms of locating willing and cooperative home owners, but for accessibility (with necessary equipment) to areas appropriate for well installation. It was desirable to use relatively light-weight auguring equipment for drilling the wells, in order to minimize any impacts to the lawns and landscaping. This was attempted initially, but found to be inadequate for drilling through the rockier portions of even the upper few feet of material.

Heavier drilling equipment was brought into both sites, and even with this equipment, wells could only be installed to a depth of approximately five and a half feet at each of the two sites before an impenetrable layer of limestone rock was encountered. The maximum depth which could be drilled was approximately the same for each of the two holes at both of the sites. It was considered likely that there was a layer of limestone rock covering a relatively large horizontal area over which effluent would tend to travel in the direction of the monitoring wells (since the monitoring wells were installed five to ten feet downhill from the nearest effluent distribution line, which was likely also over this thick layer of limestone).

All of the holes drilled at each of the two sites were found to be free of significant moisture initially. The lysimeters were rinsed with de-ionized water and bailed out after they were installed to ensure that they would be free of any contaminants from their installation. A bailing device was used for checking and removing water samples from the wells/lysimeters.

One of the two wells installed at Site 1 was found to be dry, with no sample collected from it throughout the monitoring period. The other well installed at this site was found to be productive only following significant rainfall events. One of the wells at Site 2 produced enough liquid to sample only once, shortly after its installation. As with one of the wells at Site 1, the other well at Site 2 was productive only after rainfall.

Analytical results for samples collected are presented in Table 3, and discussed in the following section. Laboratory analyses of samples collected during this phase of the study were performed by the Lower Colorado River Authority Environmental Laboratory.

<u>Summary and Discussion of Results of Residential Systems Monitoring</u>

As noted above, the monitoring wells only produced sufficient moisture for sample collection following periods of significant rainfall. This appears to indicate that evapo-transpiration processes were responsible for most of the water losses from the soil system during periods of dry weather, and preventing significant downward migration of septic system effluent.

Fecal coliform are used as indicator bacteria for the potential presence of pathogens from human wastes. Measured levels of fecal coliform as compared with fecal streptococcus from both sites tend to indicate human sources of pollutants versus potential animal sources in surface runoff. This result is important in that it appears likely that the well samples collected contain septic system effluent.

The average nitrate (as nitrogen) concentration measured is 2.46 mg/L for the six samples collected from both sites (the

Table 3
Residential Systems Monitoring Results

Site 1:

Hole #	Parameter	Units	Concentration
1	Fecal Col.	/100 ml	>200,000
1	Fecal Strep.	/100 ml	80
1	NO3-N/NO2-N	mg/L	2.197
1	TKN	mg/L	2.574
1	Fecal Col.	/100 ml	28,000
1	Fecal Strep.	/100 ml	370
1	NO3-N	mg/L	2.229
1	TKN	mg/L	0.15
1	Fecal Col.	/100 ml	4,800
1	Fecal Strep.	/100 ml	0
1	NO3-N	mg/L	3.093
1	TKN	mg/L	17.261

Site 2:

Hole #	Parameter	Units	Concentration
1	Fecal Col.	/100 ml	>20,000
1	Fecal Strep.	/100 ml	1,050
1	NO3-N	mg/L	0.86
1	TKN	mg/L	1.321
2	Fecal Col.	/100 ml	>200,000
2	Fecal Strep.	/100 ml	3,000
2	NO3-N	mg/L	0.024
2	TKN	mg/L	4.54
2	NO3-N	mg/L	6.339
2	TKN	mg/L	2.646

nitrite concentration for the analysis which includes nitrate and nitrite is considered to be negligible here). The average total Kjeldahl nitrogen (TKN) measured is 4.75 mg/L.

Total nitrogen measurements (not including nitrite-nitrogen in five of the samples) from these six samples were on the average about 7.2 mg/L. It was not possible with these particular systems to sample the effluent from the septic tank before it entered the distribution lines to determine the removal occurring for these parameters. However, accepted average total nitrogen levels for septic system effluent are about 40 to 45 mg/L. Assuming that these homes produced wastewater with average concentrations of these constituents, the removal observed for nitrogen was surprisingly good for the few samples that could be collected during the study.

Both residential sites had fully developed lawns throughout the areas over the effluent distribution systems. Uptake of nitrogen by vegetation, and nitrification/denitrification processes might both be mechanisms responsible for any nitrogen removal occurring for these systems.

The fecal coliform counts for both of the residential sites were surprisingly high, and particularly so considering the nitrogen levels measured for those same samples. It appears that the bacteria aren't being adequately filtered through the soil/subsurface conditions, and are being transported with flow through either fractured or karst limestone, or along lateral bedding planes.

In all cases the nitrate-nitrogen concentrations were very low. In only one case was the TKN relatively high. As compared with the other samples taken, the results of this particular sample are interesting, since the fecal coliform count was much lower than for the other samples. While the few number of samples which could be collected from the monitoring wells during this study could not be considered a statistically representative number for performance of systems in these conditions, it does suggest that at least some of the conventional onsite disposal systems may be providing better nitrogen removal than was previously suspected. Significantly more monitoring data, for a larger number of systems installed in these conditions, and for a longer duration of monitoring, is necessary before definite conclusions can be drawn regarding the performance of conventional onsite systems in these geologic conditions.

CONCLUSIONS AND RECOMMENDATIONS

Caliche-type soils are common to large areas of the central Texas hill country, including those recharging the Edwards Aquifer. Many of these areas have lower population densities, and rely heavily upon onsite wastewater treatment systems for cost-effective wastewater service. The evaluation of the performance of existing systems in these conditions is essential for ensuring adequate environmental and public health protection, and for determining what level(s) of pretreatment may be necessary prior to final onsite disposal of wastewater effluent in these soils.

Both the laboratory column studies and monitoring of the two residential systems produced very interesting results. It was observed from the laboratory studies that nitrification readily occurred in both the caliche and the sandy loam soils. Total phosphorus removal was also very good for all of the soils tested, as would be expected in soils of their pH range.

The average nitrate-nitrogen removal observed for most of the soil columns was very similar, with caliche soil Column #7 showing significantly less removal without any pretreatment. When pretreatment by sand filtration and organic carbon addition was used prior to applying the effluent to Column #7, after a period of several weeks the nitrate concentration in the column effluent was at non-detectable levels.

Because clogging of most of the columns prevented observing their performance for a longer period of time, it is not known whether the average nitrate-nitrogen removal for all of the caliche soil columns would differ significantly from the sandy loam. As discussed above, a trend toward increased nitrate-nitrogen removal was observed over time for the sandy loam soil, whereas the opposite trend was observed at least to some extent for all of the caliche soil columns tested.

The sand filtration and carbon addition set-up used to enhance nitrogen removal in the laboratory worked relatively well, with the exception of problems due to increasing clogging in the upper few inches of the sand column. Increasing time was required for the filtration process, as would be expected for a ripening sand filter. This highlights the need for regularly scheduled inspection and maintenance of systems which include a filtration process.

Field monitoring results for the two residences showed low levels of nitrate-nitrogen, and in all but one sample low concentrations of Kjeldahl nitrogen, but fairly high levels of fecal coliform indicator bacteria in all samples. This appears to indicate that nitrogen from these two conventional treatment systems is either being removed through plant uptake or nitrification/denitrification processes, or otherwise immobilized in the upper soil/limestone matrix.

Further monitoring of systems in these geologic conditions is recommended to adequately evaluate the performance of existing conventional onsite wastewater treatment system designs. Subsurface conditions in the central Texas hill country where weathered limestone/caliche soils are common can vary greatly for different sites, and even within the same lot. Therefore, to provide enough performance data for systems in these karst, fractured, and/or weathered limestone conditions, it is essential that a relatively large number of systems (on the order of twenty to thirty over a period of several years) be monitored so that the set of sites and data is as representative as possible.

In addition to further monitoring of systems to better evaluate both nitrogen and pathogen removal performance, consideration should be given to cost-effective designs which will enhance pathogen and nitrogen reduction, and minimize the potential for migration of these pollutants to surface or ground water supplies.

Acknowledgements:

The Texas Onsite Wastewater Treatment Research Council;
The City of Austin, Center for Environmental Research at the Hornsby Bend WWTF;
The Austin-Travis County Environmental Health Department staff;
The City of Austin Water & Wastewater Utility Laboratory Services staff;
Soil science staff of the U.S. Soil Conservation Service office in Temple, Texas;
Mr. Frank Hulsey, former University of Texas at Austin Dept. of Civil Engineering staff member, for the countless hours spent in the laboratory assisting with details of the soils column set-up and associated analyses; and
The residents of western Travis County who provided us with monitoring sites, and extended their patience, cooperation, and support for this project.

ATTACHMENT 1

Soils Analyses Reports

ANALYSIS REPORT

UNIVERSITY STATION, BOX X
AUSTIN, TEXAS 78713-7508
(512) 471-7721 (ext. 426)

MINERAL STUDIES LABORATORY
BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

STEVEN W. TWEEDY
CHIEF CHEMIST

INVESTIGATOR:	PROJECT/ACCOUNT:	DATE:	REPORT #:
S. Parten	Caliche Soils 26-4227-0650	November 21, 1991	R-068-91

MSL ID#: 91-371, -372, -373

SAMPLE PREPARATION / TREATMENT

These samples were crushed then pulverized in a tungsten carbide shatterbox. The resulting powders were then subsampled for each of the requested analyses.

SAMPLE ANALYSIS METHODS

Constituents	Technique	MSL Procedure #
Whole Rock Mineralogy	X-Ray Diffraction	MSL 001
Percent clay (<4 um)	Carbonate removal Hydraulic separation Pipet/gravimetric	MSL 001
pH and Elec. Cond.	1:1 Extraction Measure of supernatant	USDA HB#60
Total Organic Carbon	Coulometric (TC-MC)	ref: SWI 1.7
Cation Exchange Capacity	NaOAC/NH4OAC-ICP(Na)	USDA HB#60

RESULTS

MSL ID#	SPL ID#	MINERALS FOUND BY XRD:
91-371	#1 WALNUT	Calcite, Quartz, K-feldspar, clay
91-372	#2 EDWARDS	Calcite, Quartz, clay
91-373	#3 CA SANDY LOAM	Quartz, Calcite, Dolomite, feldspar, clay

See also: (attached) XRD scans.

SPL#	DOLOMITE (WT%)	CALCITE (WT%)	CLAY (WT%)	TOC (%C)	pH(1:1) (units)	E.C.(1:1) (mmho)
#1 WALNUT	-	78.4	10.9	0.17	8.38	0.177
#2 EDWARDS	-	80.3	12.9	0.20	8.20	0.230
#3 CA SNDYLM	*1.9	18.0	16.3	0.42	8.21	0.377

< less than indicated value
* reported value near detection limit
nd - not determined
ins - insufficient sample

ANALYSIS REPORT

UNIVERSITY STATION, BOX X
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STEVEN W. TWEEDY
CHIEF CHEMIST

MSL #	SPL #	CATION EXCHANGE CAPACITY (meq/100g)
91-212	GLEN ROSE GRAY /1	6.2
91-213	GLEN ROSE YELLOW /2	6.5
91-214	EDWARDS /3	11.3
91-371	WALNUT /1	8.8
91-372	EDWARDS RED /2	13.7
91-373	CA SANDY LOAM /3	15.4

QUALITY ASSURANCE ANALYSES:

NBS-1A (NBS-LIMESTONE) TOTAL CARBON ANALYSIS:

FOUND: 9.79 WT% VS ACCEPTED: 9.75 WT% (100.4% RECOVERY)

NBS-1A (NBS-LIMESTONE) MINERAL CARBON ANALYSIS:

FOUND: 9.11 WT% VS ACCEPTED: 9.14 WT% (99.7% RECOVERY)

COMMENTS

Please contact me at 471-0426 with any questions or comments regarding these results.

SAMPLE DISPOSITION:

These samples are being returned to you by campus mail.

ANALYSTS:

Goldsmith
Tsai
Blass
Tweedy

< less than indicated value
* reported value near detection limit
nd - not determined
ins - insufficient sample

ANALYSIS REPORT

UNIVERSITY STATION, BOX X
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'2) 471-7721 (ext. 426)

MINERAL STUDIES LABORATORY
BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

STEVEN W. TWEEDY
CHIEF CHEMIST

INVESTIGATOR:	PROJECT/ACCOUNT:	DATE:	REPORT #:
S.Parten / H.Liljestrand	UT Civil Engineering	June 27, 1991	R-031-91

MSL ID#: 91-212, 91-213, 91-214

SAMPLE PREPARATION / TREATMENT

These samples were crushed then pulverized by hand in a mortar and pestle. The resulting powders were then subsampled for each of the requested analyses.

SAMPLE ANALYSIS METHODS

Constituents	Technique	MSL Procedure #
Whole Rock Mineralogy	X-Ray Diffraction	MSL 001
Percent clay (<4 um)	Carbonate removal Hydraulic separation Pipet/gravimetric	MSL 001
pH and Elec. Cond.	1:1 Extraction Measure of supernatant	
Total Organic Carbon	Coulometric (TC-MC)	ref: SWI 1.7

RESULTS

MSL ID#	SPL ID#	MINERALS FOUND BY XRD:
91-212	(1) gray	Calcite, Dolomite, Quartz
91-213	(2) milky yellow	Calcite, Dolomite, Quartz
91-214	(3) TDHPT	Calcite, Quartz

See also: (attached) XRD scans.

MSL#	SPL#	DOLOMITE (WT%)	CALCITE (WT%)	CLAY (WT%)	TOC (%C)	pH(1:1) (units)	E.C.(1:1) (mmho)
91-212	(1)	24.2	61.2	10.3	0.38	7.71	1.96
91-213	(2)	10.0	64.2	9.3	0.21	8.04	0.18
91-214	(3)	<3.0	79.0	12.8	0.11	8.21	0.45

< less than indicated value
* reported value near detection limit
nd - not determined
ins - insufficient sample

ANALYSIS REPORT

UNIVERSITY STATION, BOX X
AUSTIN, TEXAS 78713-7508
'2) 471-7721 (ext. 426)

MINERAL STUDIES LABORATORY
BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

STEVEN W. TWEEDY
CHIEF CHEMIST

QUALITY ASSURANCE ANALYSES:

NBS-1A (NBS-LIMESTONE) TOTAL CARBON ANALYSIS:
FOUND: 9.84 WT% VS ACCEPTED: 9.75 WT% (100.9% RECOVERY)

NBS-1A (NBS-LIMESTONE) MINERAL CARBON ANALYSIS:
FOUND: 9.13 WT% VS ACCEPTED: 9.14 WT% (99.8% RECOVERY)

COMMENTS

Your request to measure CEC on these samples cannot be accomplished at this time or in the near future due to a high level of project work pending at the lab.

We will retain enough sample for the CEC measurement as we discussed on the phone 6/27/91.

Please contact me at 471-0426 with any questions or comments regarding these results.

SAMPLE DISPOSITION:

The bulk of these samples is being returned to by campus mail.

ANALYSTS:

Goldsmith
Tweedy
Herrera

< less than indicated value
* reported value near detection limit
nd - not determined
ins - insufficient sample

ATTACHMENT 2

Materials and Methods of Column Construction

ATTACHMENT 2
Materials and Methods of Column Construction

A. Materials:

- 8" and 12" Schedule 80 PVC, 20′ sections
- Flanges, 8" and 12" (2/connection) with gaskets
- End caps
- Swagelok fittings, nylon, 3/8" ID, bored through, pipe threaded
- 3/8" OD polyethylene tubing
- Bolts, nuts, and washers to fit flanges
- Sand, and #6 uniformly graded pea gravel/sand
- Plumbers tape.
- Metal wire/rod small enough, and long enough to fit into tubing, and extend beyond the tubing length by at least 2 to 3 inches.

B. Construction:

1. Cut pipe to desired length. Keep each section no longer than 3′ to 3-1/2′ so that it's possible to reach far enough into columns to install tubing and make adjustments.

2. Glue on end caps (blind flanges can be used instead of end caps so that they can be removed).

3. Drill holes at sample, inlet and drain intervals/locations. Use size appropriate for tapping holes to fit Swagelok fittings.

4. Tap holes to fit Swagelok fittings.

5. Install Swagelok fittings into bottom half/section of column. Wrap plumbers tape around fitting prior to installation.

6. Drill 1/8" holes (5) into tubing. Mark ends of tubing so that the location of holes on the tubing is known by looking at the ends.

7. Place small sized sand into bottom of lower half of column, up to level of drain ports.

8. Insert tubing into Swagelok fittings, and center drilled holes as desired. Adjust angle to about 15 degrees from vertical so that blockage by small soil particles entering the holes is minimized. Tighten fittings.

9. Cover tubing with 2 inches of #6 sand/gravel.

ATTACHMENT 2 (Continued)

10. Weigh out soil, and pour enough into column so as to end up with a 6" lift after compaction.

11. Compact soil with standard proctor, using appropriate number of blows (226 for 12" column).

12. Scarify/scrape surface of each lift.

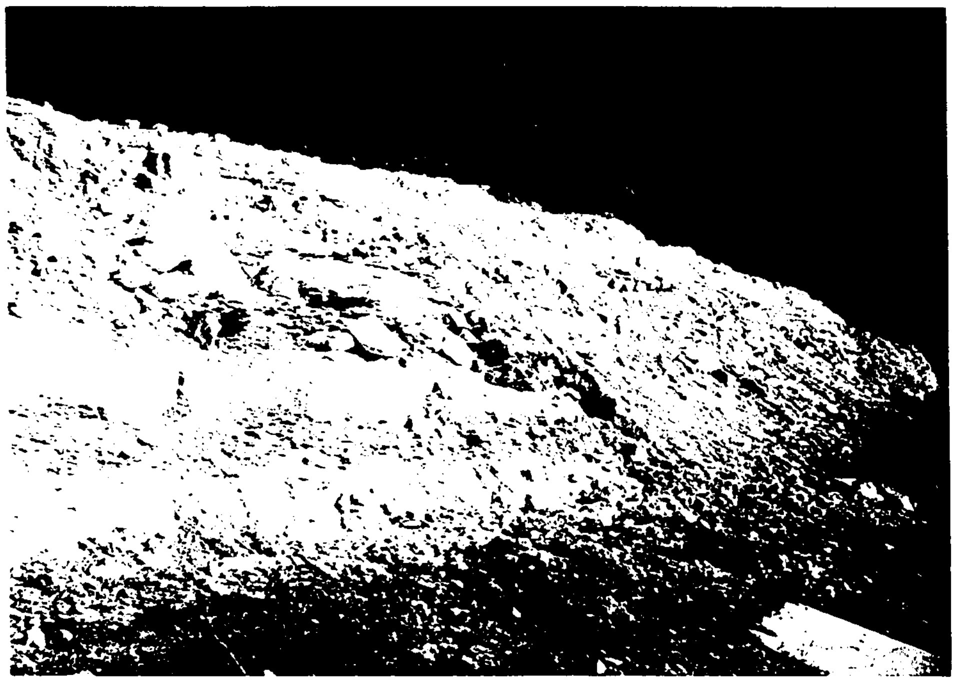
13. When enough lifts have been placed, scarify the last compacted lift, and place gravel, with perforated tubing for influent wastewater placed at the top of the gravel layer, with a layer of sand above that, and top soil above the sand.

ATTACHMENT 3

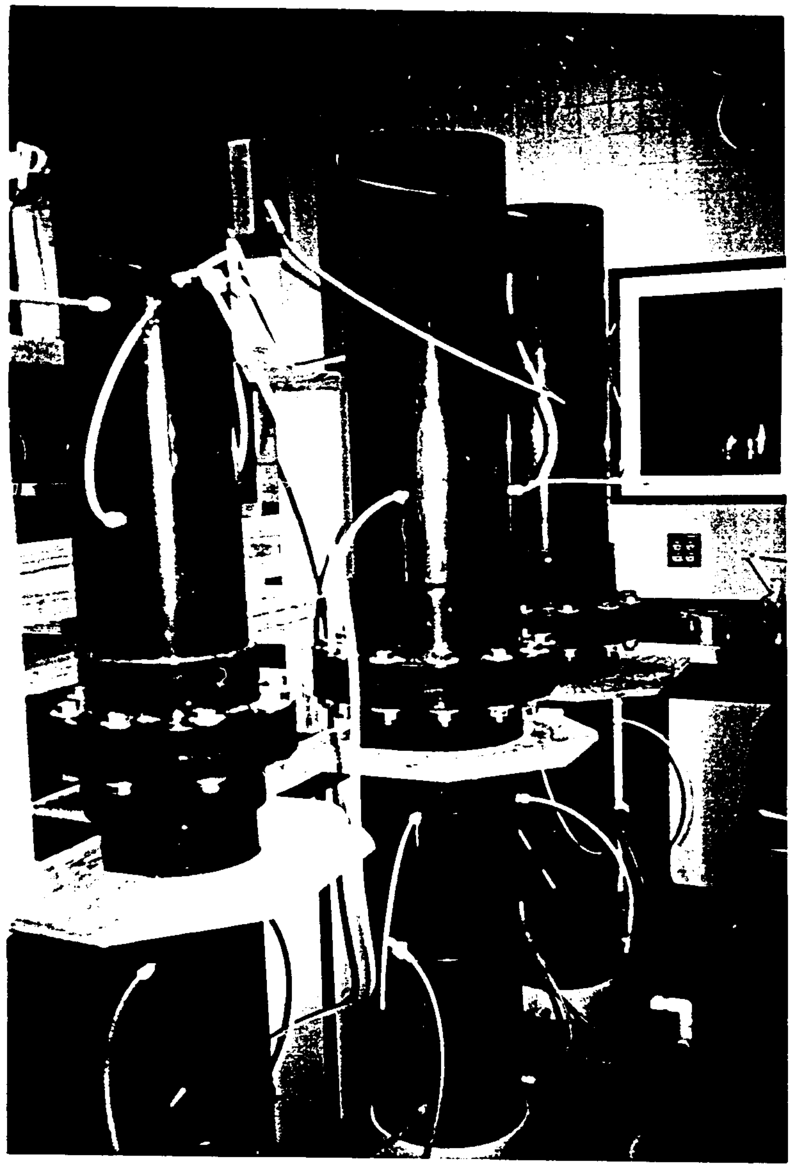
Project Photographs

Site where caliche soil samples obtained for column studies. Area was identified as overlying Walnut formation.

Area identified as overlying the Glen Rose formation where soil samples for laboratory column studies were obtained.

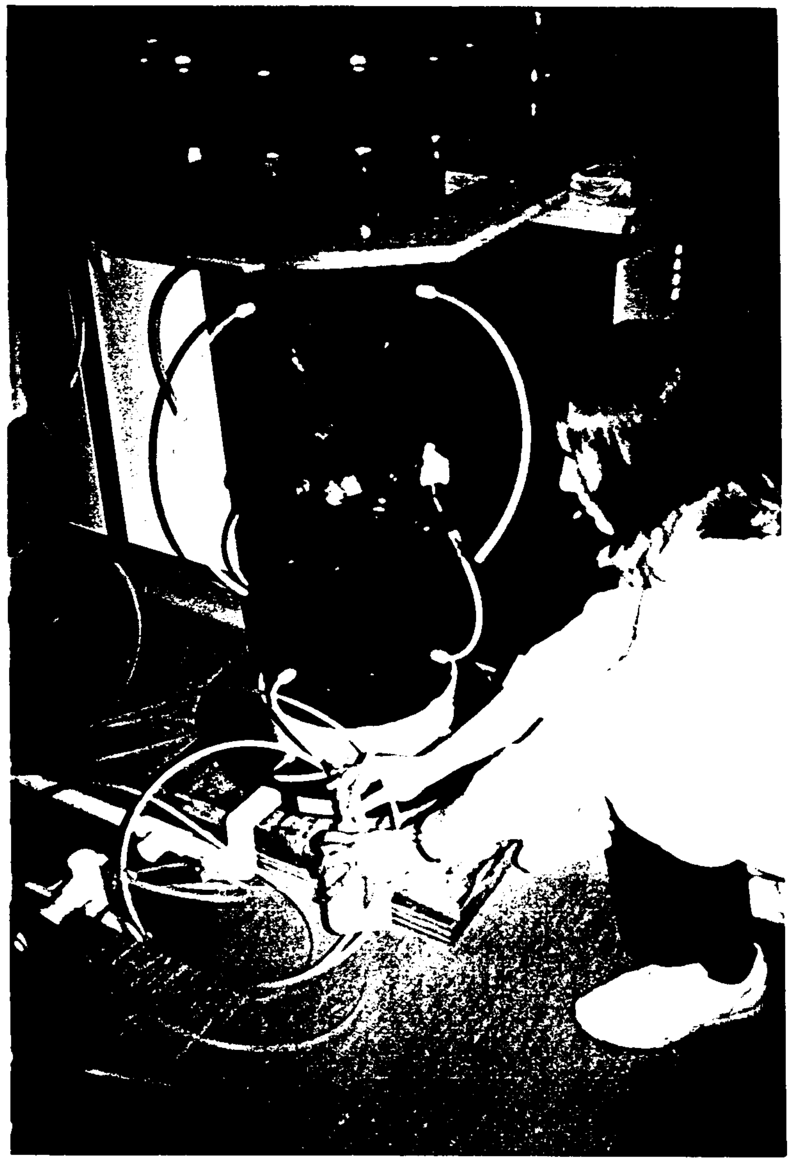


Area in Edwards Aquifer recharge zone where soil was obtained for column studies. Photograph shows horizons of weathered bedded limestone intermixed with clayey soils, and fractured limestone outcrop.



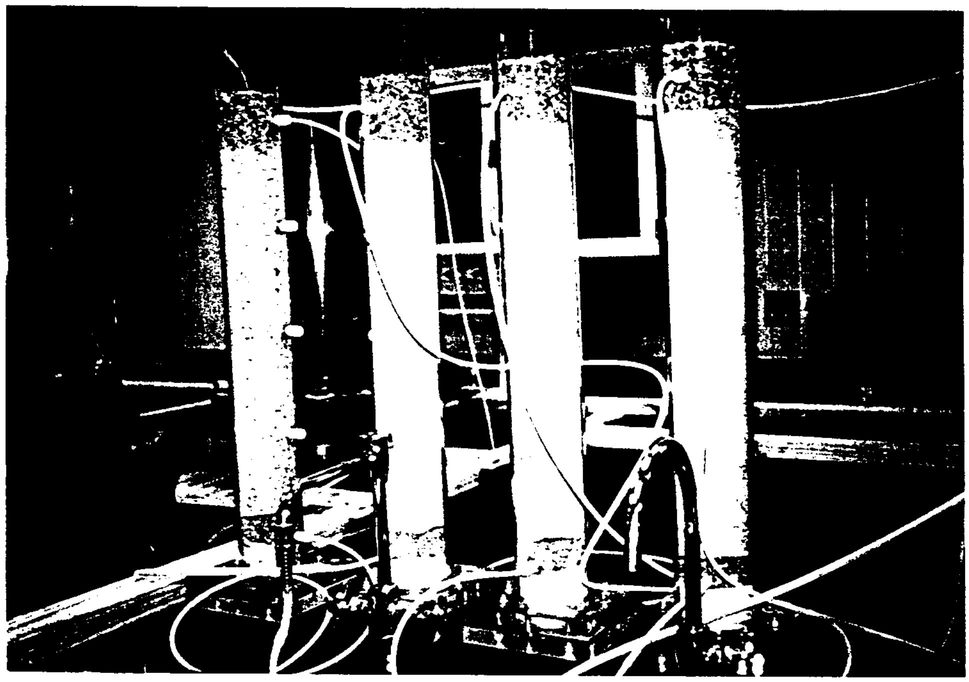
Laboratory soil column testing set-up at the Center for Environmental Research, located at the City of Austin's Hornsby Bend WWTF.

At right, effluent sample being collected from the lowest sampling port in one of the soil columns at the CER laboratory.



Below, septic holding tank for wastewater, installed into the side of a hill near the hyacinth building at the Hornsby Bend WWTF. Cleanouts for drain line are shown below tank, and 16" lid where the company supplying the septic wastewater discharges into the holding tank (local septic tank pumping company).

Four small columns filled with various grades of sand and fine gravel which were tested for their nitrification performance. The column on the far right containing the finest grade of sand (fill sand) was selected for use in the short-term enhanced nitrogen removal testing.



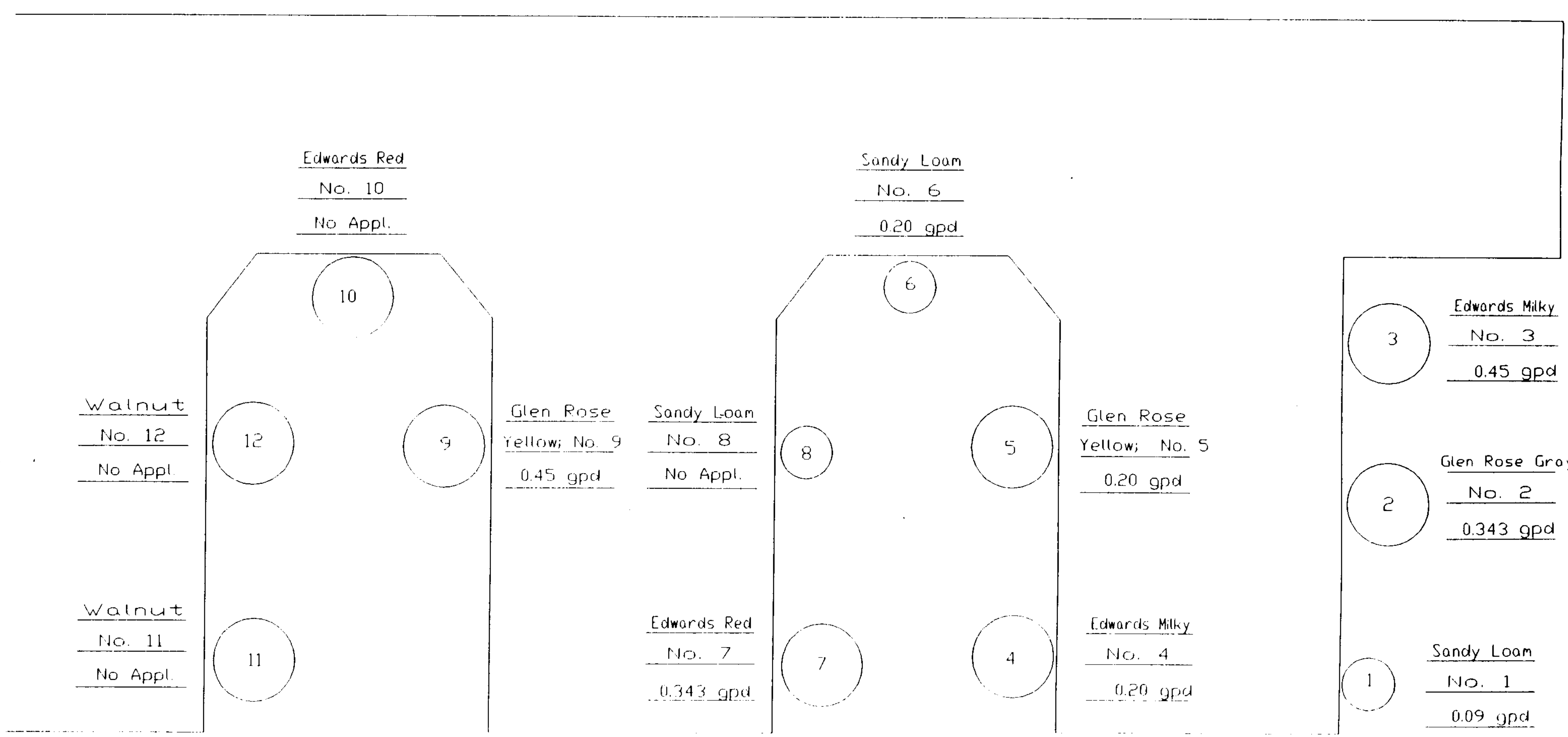
Small sand filtration column, showing clogging layer formation at top.

ATTACHMENT 4

Sketch of Column Set-up In the CER Laboratory
At the Hornsby Bend WWTF

ATTACHMENT 4

Schematic of Column Set-up in CER Laboratory



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